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BUD CHARACTERISTICS OF PONDEROSA PINE RELATED TO POTENTIAL
DAMAGE BY THE EUROPEAN PINE SHOOT MOTH

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V. M. Carolin, Research Entomologist, and J. W. Baxter^{1/}

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ABSTRACT

CURRENT SERIAL RECORDS

Bud characteristics of young ponderosa pine in open stands were studied as a possible basis for determining susceptibility or resistance of these stands to the European pine shoot moth. A survey of numbers and sizes of buds on branch apices showed three different bud patterns in eastern Oregon and Washington, and a fourth pattern in the Willamette Valley of Oregon. A study of resin canal development at two plots in northeastern Oregon showed that terminal buds had more and larger longitudinal resin canals than did lateral buds in the same cluster, and that elongation of resin canals occurred more rapidly in terminal buds. In July 1964, resin canal development in ponderosa pine in northeastern Oregon was much more advanced than it was on Scotch pine in the shoot moth-infested Puget Sound area. Bud number and size and probable differences in resin production between terminal and lateral buds should be tested in natural pine stands as indicators of resistance to the European pine shoot moth.

The European pine shoot moth, *Rhyacionia buoliana* (Schiff.), poses a potentially serious threat to western pine forests. It now infests pine ornamentals, nursery stock, and Christmas tree plantations in much of western Washington and in a few localities in Oregon and British

^{1/} Teacher in Biological Sciences, The Dalles High School, at The Dalles, Oreg., employed as Biological Aid during these studies.

Columbia. Research is needed to determine whether or not this insect will become a serious pest in young forest stands of ponderosa (*Pinus ponderosa*) and lodgepole (*P. contorta*) pines.

Growth characteristics of host pines apparently affect the amount of shoot moth damage. Rapid height growth of red pine (*Pinus resinosa*) has been associated with reduced susceptibility to shoot moth damage (Heikkinen and Miller 1960), and number and size of leader buds influence the impact of larval feeding (Miller 1967). Survival of larvae on Scotch pine (*Pinus sylvestris*) was related to the amount of resin encountered during the initial attack on the buds; differential development of the insect and the resin canals was suggested as a factor in larval survival, with warm summers favoring larval attack before resin canals were well developed (Harris 1960). Harris noted that resin flow of lodgepole pine did not inhibit shoot moth attack and suggested that some resins were more readily emulsified than others by the larval vomitus. In studies of *Rhyacionia* spp. on southern pines, Yates (1966) considered differential host injury to be a result of effects of oleo-resin on feeding larvae.

"Inherent differences in susceptibility are found between pine species and are suspected at a subspecific level" (Holst and Heimbürger 1955). Susceptibility is difficult to evaluate under planted conditions. Holst and Heimbürger (1955) state that variation in susceptibility seems to be caused by (a) possible variation in seed source and (b) degree of matching of the planting site to the site requirements of the planted materials, especially in respect to climate. Possibilities for breeding for resistance, in pines of the *Lariciones* and *Insignes* groups, for Ontario conditions were described by Holst (1963).

Whether species characteristics of western hard pines, particularly ponderosa, would permit survival and population buildup of European pine shoot moth and result in economic damage in the pine region remains to be shown. An economic evaluation by Flora (1965), based on analogy with Lake States conditions, assumes that severe damage to ponderosa pine will occur on poor sites and some damage on medium sites, except in those areas where low winter temperatures kill or limit the spread of the shoot moth. However, the concept of site, in the sense of the mensurationist, may be misleading; the key need seems to be recognition of specific site factors affecting establishment and multiplication of the shoot moth in young stands. The hazard is chiefly to young trees, and morphological indicators of tree condition are sorely needed. Surprisingly, two recent bibliographies on ponderosa pine (Cummings 1967; Axelton 1967) indicate a minimum effort in this direction.

In areas of the Pacific Northwest, we studied bud characteristics of ponderosa pine in 1964 and 1965 to obtain information related to possible susceptibility of this host to the shoot moth. The findings

will aid in formulating studies in natural pine stands for evaluating the biological threat to ponderosa pine. Similar studies on lodgepole pine are also planned.

OBJECTIVES

The broad purpose of the study was to determine the extent of morphological differences between apical bud clusters in ponderosa pines growing in different localities and between buds in the same cluster on individual trees. A standard condition imposed was that pines should be approximately even aged and growing in openings without an immediate overstory.

Presence and characteristics of lateral buds were a key to differences between localities and between buds in the same cluster. Because of the possible significance of resin flow as a factor in increasing tree resistance, differences in resin canal development between buds were of particular interest.

Therefore, specific objectives were to determine:

1. Numbers and sizes of buds per apical cluster on young ponderosa pines in various eastern Oregon and Washington localities.
2. Characteristics of resin canal development in ponderosa pine buds in one area in the pine region.

In addition, timing of shoot moth attack in the Puget Sound area, in relation to resin canal development, was briefly explored.

METHODS

The longitudinal dimension of a bud has been described both as length (Mergen et al. 1960) and height (Harris 1960). In this paper, "bud length" is used to describe external measurement of the bud, including the scale covering, and "bud height" to describe internal measurement of the growing bud, with the scale covering removed. Resin canal development is described in reference to bud height, hence the term "resin canal height" is used.

Bud Complement

At 10 locations known to have young open-grown pines, observations were made after bud elongation appeared completed. Bud measurements

were obtained at two locations in northeast Oregon during August 18-19, 1964, and at eight other locations during August 30 - September 2, 1965.^{2/} Five pines per location, in a general height class of 7 to 12 feet, were sampled; apical bud clusters were examined on two branches from each of the upper, middle, and lower third of the crowns. Numbers of terminal and lateral buds in each cluster were recorded for each branch, and length and maximum width of each bud were measured. In addition, total height and crown length of each tree were recorded.

Measurements from the five trees were averaged by crown third to determine: (1) average length and width of terminal as compared with lateral buds to the nearest 0.5 mm. (millimeter), and (2) average number of lateral buds per 10 terminal buds. Averages for the different locations were compared for evidence of different bud complement patterns. In addition, the range in which 80 percent of all measurements for a single pattern occurred was used to show the probability that the patterns were different.

Observations were made at two points in the Willamette Valley of Oregon, to deduce differences in bud complement possibly attributable to climatic factors. In 1965, a group of trees, planted as 2-0 stock in fall 1958 at a study site in Portland, was sampled; seedlings were obtained from a central Oregon forest nursery. The results stimulated a search for native ponderosa pine in the general vicinity, and in fall of 1967, records on bud size and number were obtained for trees near Turner, about 45 miles to the south of Portland.

Bud and Resin Canal Development

Studies were conducted in 1964 on two plots in northeast Oregon, near Union; one plot was at an elevation of 4,100 feet and the other at 5,100 feet. Temperature and humidity were recorded at the 4,100-foot plot. Observations began at the 4,100-foot plot on July 2 and at the 5,100-foot plot on July 8.

Bud structure and growth.--The external characteristics of ponderosa pine buds were noted in order to develop methods for sectioning buds. Internal characteristics studied were limited to longitudinal resin canals and pith; histogenesis in the bud axes of *Pinus lambertiana* and *P. ponderosa* has been described by Sacher (1954). Seasonal growth characteristics were deduced from surplus bud material collected at the 4,100-foot plot and held in alcohol.

^{2/} Locations sampled in 1964 were Bennett Peak and Dooley Mountain (Wallowa-Whitman National Forest); in 1965, Bear Springs (Mount Hood National Forest), Pole Creek Road (Deschutes National Forest), Brush Creek Road (Ochoco National Forest), Dixie Pass and Deer Creek Road (Malheur National Forest), Bull Prairie Guard Station (Umatilla National Forest), Monument Road (Goldendale, Wash.) and Naches Ranger Station (Snoqualmie National Forest).

Resin canal development.--Number, height, and diameter of longitudinal resin canals were compared between terminal and lateral buds in apical clusters. Terminal buds were sectioned weekly at both plots beginning July 8; regular examination of lateral buds began on July 29, when internal elongation was sufficient to define sectioning points. Approximate elongation of resin canals in lateral buds prior to July 29 was later determined by sectioning surplus material held in alcohol. Weekly observations continued until September 9, when bud growth appeared ended.

Two apical bud clusters were removed from branches in the middle crown of each of five pines. Bud clusters were placed in 70 percent alcohol for a week to clear the resin canal openings. Buds were then sectioned with a razor blade at two-thirds height and one-third height after the bud sheath was removed. If no resin canal development was visible at two-thirds height, a section was made at one-half height. For each section, number and diameter of resin canals and diameter of the pith, inside the circlet of resin canals, were recorded. Figure 1 shows the appearance of a terminal and one lateral bud sectioned at one-third bud height.

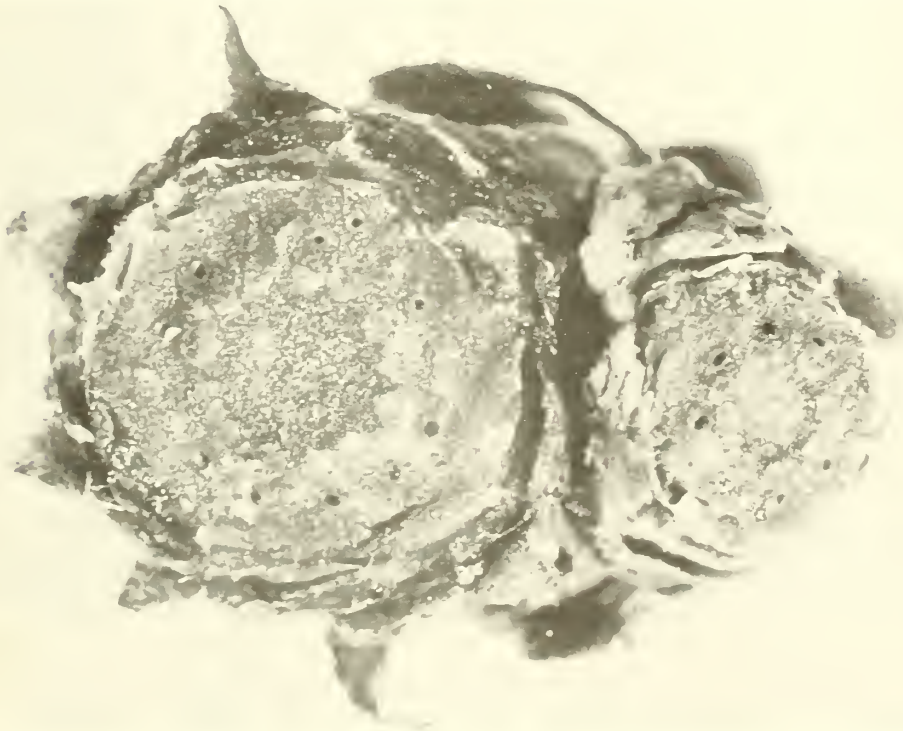


Figure 1.--Terminal bud and associated lateral bud of ponderosa pine sectioned at one-third bud height; 4,100-foot plot, August 5, 1964. (X12)

Resin canal diameter was measured under a microscope by insertion of tapered micropins, cut off at different distances from the tip, into the canal opening. Bent portions of micropins laid across the pith measured pith diameter. The two series of measuring pins were given numbers to designate relative size classes, which were entered on data cards. Later, the pins were calibrated, and size classes were converted to measurements expressed in hundredths of millimeters. Most size classes for resin canals were 0.05 mm. apart. Those for pith diameter were mostly 0.16 to 0.38 mm. apart with interpolation as needed; size classes were selected according to periodic changes in pith diameter.

Resin Canal Development and Time of Shoot Moth Attack

Perspective on resin canal development in relation to shoot moth attack of buds was sought by a carefully timed observation at Mercer Island, Wash. On July 31, 1964, at the time attack on buds was just commencing, a group of four Scotch pines, 10 to 12 feet high, was sampled for resin canal development. All buds on 23 apical bud clusters, consisting of 23 terminal buds and 87 lateral buds, were sectioned to determine number, diameter, and height of resin canals. This group of pines had been observed since 1961, and moderate damage was known to occur consistently on these trees.

RESULTS

Bud Complement

Three distinct bud patterns were indicated by the bud counts and measurements at points in eastern Oregon and Washington. These are best described by size of terminal buds in the upper-crown third and relative numbers of lateral buds at different crown positions (table 1). In the most common pattern, found at six plots, 80 percent of all terminal buds in the upper crown were 10 to 17 mm. long and usually accompanied by one lateral bud. Numbers of lateral buds were progressively less with decreasing crown height. A second pattern was indicated by small terminal buds, all 7 to 10 mm. long in the upper crown, with very few lateral buds in the upper and middle crown and none in the lower crown. A third pattern was characterized by large terminal buds, with 80 percent of all buds in the upper crown 18 to 28 mm. long and nearly always accompanied by one or two lateral buds; lateral buds usually accompany terminal buds on middle and lower crown branches.

The bud complement on trees at two locations in the Willamette Valley was strikingly different. These pines had larger terminal buds than trees sampled in east-side natural stands and almost twice as many lateral buds as the most heavily budded trees in east-side stands.

Table 1.--Possible bud complement patterns on young ponderosa pine, based on ranges in average bud size and average number of lateral buds between different geographical locations

Pattern	Number of locations	Crown height	Terminal buds		Lateral buds		Number per cluster
			Average length	Average width	Average length	Average width	
-----Millimeters-----							
1 (small buds)	2	Upper	8.4 (8.0-8.8)	4.5 (4.1-5.0)	1/ 6.2	1/ 3.4	0.2 (0 -0.4)
		Middle	6.6 (6.4-6.8)	4.0 (3.5-4.5)	3.7 (2.5-5.0)	2.5 (2.0-3.0)	1/1
		Lower	5.4 (4.5-6.3)	3.4 (2.8-4.0)	--	--	0
2	6	Upper	13.2 (11.6-16.6)	5.4 (5.0-5.9)	8.0 (6.6-9.0)	3.1 (2.7-3.4)	.6 (0.3-1.0)
		Middle	10.0 (8.4-12.7)	4.7 (4.2-5.2)	6.8 (3.9-10.0)	2.7 (2.1-3.0)	.4 (0.1-0.9)
		Lower	7.0 (6.2-8.9)	3.7 (3.4-4.2)	4.5 (3.7-4.1)	1.7 (2.2-3.0)	.2 (0 -0.4)
3 (large buds)	2	Upper	21.3 (18.9-23.7)	6.6 (6.3-7.0)	13.2 (10.5-15.9)	3.7 (3.4-4.1)	1.7 (1.4-2.1)
		Middle	15.0 (12.5-17.5)	5.3 (4.7-6.0)	9.0 (7.2-10.7)	3.0 (2.8-3.1)	1.4 (0.9-2.0)
		Lower	9.9 (9.4-10.4)	3.7 (3.6-3.9)	5.4 (5.3-5.5)	2.0 (1.9-2.1)	.5 (0.2-0.8)
4 (very large buds)	2/ 2	Upper	29.4 (25.8-33.1)	8.1 (7.1-9.1)	16.4 (13.1-19.8)	4.4 (3.8-5.1)	3.0 (2.8-3.2)
		Middle	22.0 (19.9-24.1)	6.9 (6.4-7.4)	12.0 (9.7-14.3)	3.8 (3.6-4.1)	2.8 (2.6-3.1)
		Lower	15.6 (14.8-16.3)	5.3 (5.2-5.4)	8.6 (7.7-9.6)	3.2 (3.1-3.4)	1.7 (1.7-1.8)

1/ Lateral buds were present at only one of two locations.

2/ In the Willamette Valley.

Bud and Resin Canal Development

Bud structure and growth.--The terminal bud is stout and covered with several layers of scales. During elongation, its external diameter is constant up to about half-bud height, then decreases, tapering sharply on the upper third. At first, the sheath of scales extends 3 to 5 mm. beyond the bud apex, leaving a hollow. By the end of the growing season, the bud apex fills the hollow, the upper part of the bud thickens, and the sheath tip becomes sharply pointed. Larger lateral buds are similar in shape to the terminal bud and point sharply away from it. Undersized and immature lateral buds are usually compressed against the terminal bud.

At the 4,100-foot plot in northeast Oregon, terminal buds in the middle-crown third were 8 to 12 mm. long during early July and 15 to 20 mm. long in mid-August when their height growth appeared ended. Lateral buds began to form in early July, and completed height growth late in August. Examples of bud development at 3-week intervals, starting July 8, are shown in figure 2.

At the 5,100-foot plot, terminal buds were also 8 to 12 mm. long in early July but were slightly larger than those at the 4,100-foot plot by the end of August; lateral buds lagged behind terminal buds in development. Approximate growth rate of buds at the 4,100-foot plot is shown in figure 3. Growth rate at the 5,100-foot plot is believed to be similar.

Resin canal development.--Terminal buds had more and larger resin canals and showed more rapid height growth of resin canals, than did lateral buds.

Cross sections of buds showed two general types of longitudinal resin canals. "Primary" resin canals, arranged in a circlet, were visible early in bud growth. Later, "secondary" canals--apparently, the branch canals described by Sacher (1954)--appeared. These usually were outside the circlet of primary canals.

Terminal buds showed a circlet of usually 13 primary resin canals, whereas lateral buds at 4,100 feet showed usually eight primary resin canals and those at 5,100 feet usually nine (table 2). Number of primary canals per bud was the same for both the one-third and two-thirds bud heights, until branch canals developed. Then some small variation occurred in counts where one or more branch canals developed within the ring of primary canals and was recorded as a primary canal.

In terminal buds, primary resin canals were at one-half bud height on July 2, based on observations only at 4,100 feet. These resin canals were apparent at two-thirds bud height at both elevations on July 8, but were not measurable until July 15. In lateral buds, primary resin canals reached half-bud height on July 15; they were not measurable at two-thirds bud height until July 29, 2 weeks later than in terminal buds.



A



B



C



D

Figure 2.--Examples of ponderosa pine bud development at 4,100 feet in northeastern Oregon on the following dates:
A, July 8; B, July 29; C, August 19; D, September 9.
(X2.7)

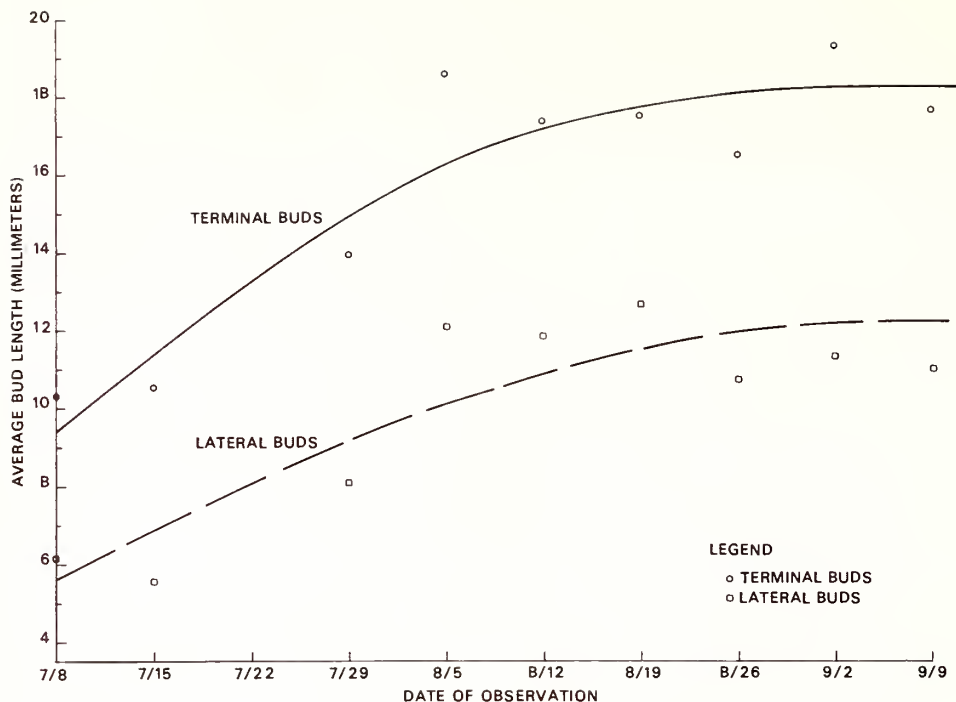


Figure 3.--Ponderosa pine bud growth at 4,100-foot elevation in northeastern Oregon.

Table 2.--Average number of primary resin canals in ponderosa pine buds at one-third bud height, two elevations

		4,100 feet		5,100 feet	
Date	:	Terminal buds	Lateral buds	Terminal buds	Lateral buds
July 2	:	12.8	--	--	--
8	:	13.0	--	13.8	--
15	:	13.4	--	13.3	--
22	:	13.0	--	13.0	--
29	:	12.9	8.0	13.1	8.0
Aug. 5	:	13.0	8.0	(1/)	(1/)
12	:	15.2	9.4	12.6	10.1
19	:	12.8	8.0	13.3	9.1
26	:	13.0	8.6	12.7	9.4
Sept. 2	:	12.8	8.1	13.1	8.7
9	:	12.8	9.8	13.9	11.5
Average	:	13.3	8.6	13.2	9.5

1/ Heavy rainstorm cut off access to this plot on date of scheduled examination.

Branch canals were first noted at one-third bud height on August 12, in both terminal and lateral buds and at both plots. In terminal buds, these canals were common at two-thirds bud height on August 26 and readily identified. In lateral buds, they also occurred at two-thirds bud height on this date but in small number. At this position in the bud, they tended to appear within the circlet of primary canals, and were usually recorded as additional primary canals.

Branch canals were about twice as numerous in terminal buds as in lateral buds on a given collection date, ranging as high as 20 in terminal buds and 12 in lateral buds. Because these arise by branching from primary canals, the difference in numbers is due to the larger number of primary canals in terminal buds. Within the sample of terminal and lateral buds examined on a given collection date at each plot, variation in number of branch canals was considerable. Variation between dates was also large, no doubt due to inconsistency in selecting sectioning points as well as variation in bud development.

Average diameter of primary resin canals was generally greater in terminal buds than in lateral buds (table 3). An odd finding was that, after July 29, average diameter of primary resin canals at one-third bud height decreased. This was thought to be an artifact resulting from either: (1) selection of large buds early in the period of observation, or (2) gradual shifting upward of sectioning points as the internal shoot apex elongated. When collection date was ignored, regression analysis showed a significant linear relationship between diameter of primary resin canals and pith diameter in both terminal and lateral buds at both plots. (In three regressions, the linear effect was significant at $p = 0.01$; the regression for lateral buds at 5,100 feet showed a cubical as well as a linear effect at $p = 0.05$.) Regression lines for terminal buds at the two elevations were similar; those for lateral buds at the two elevations were also similar (fig. 4).

If we can assume pith diameter is indicative of size of bud, the regression shows that larger resin canals are found in larger buds, regardless of time of year. Thus, the measurements were consistent and apparently in line with results by Harris (1960) showing actual resin production to be proportional to bud size.

Average diameter of branch canals was less than that of primary canals in the same bud at the same height. No real comparison could be made between terminal and lateral buds; most branch canals were small--0.05 mm. or less in diameter. A few, however, were of the same size and in approximately the same position as the primary canals.

Table 3.--Average diameters of pith and primary resin canals in ponderosa pine buds at one-third bud height and at two elevations; July 2 to September 9, 1964

Date	Elevation, 4,100 feet				Elevation, 5,100 feet			
	Terminal buds		Lateral buds		Terminal buds		Lateral buds	
	: Resin :		: Resin :		: Resin :		: Resin :	
	Pith	canals	Pith	canals	Pith	canals	Pith	canals
-----Millimeters-----								
July 2	1.80	0.10	--	--	--	--	--	--
8	1.85	.13	--	--	2.37	0.15	--	--
15	2.60	.19	--	--	2.72	.20	--	--
22	2.70	.19	--	--	2.59	.15	--	--
29	2.89	.15	0.93	0.13	2.82	.18	1.05	0.13
Aug. 5	2.41	.11	.88	.09	(1/)	(1/)	(1/)	(1/)
12	1.73	.09	.70	.08	2.13	.11	.88	.09
19	1.41	.10	.64	.10	2.72	.14	.88	.11
26	2.04	.13	.80	.09	2.41	.16	.75	.11
Sept. 2	1.90	.10	.81	.09	1.96	.11	.69	.09
9	1.47	.07	.74	.07	1.58	.07	.83	.07

^{1/} Observations not made because road was washed out by rainstorm.

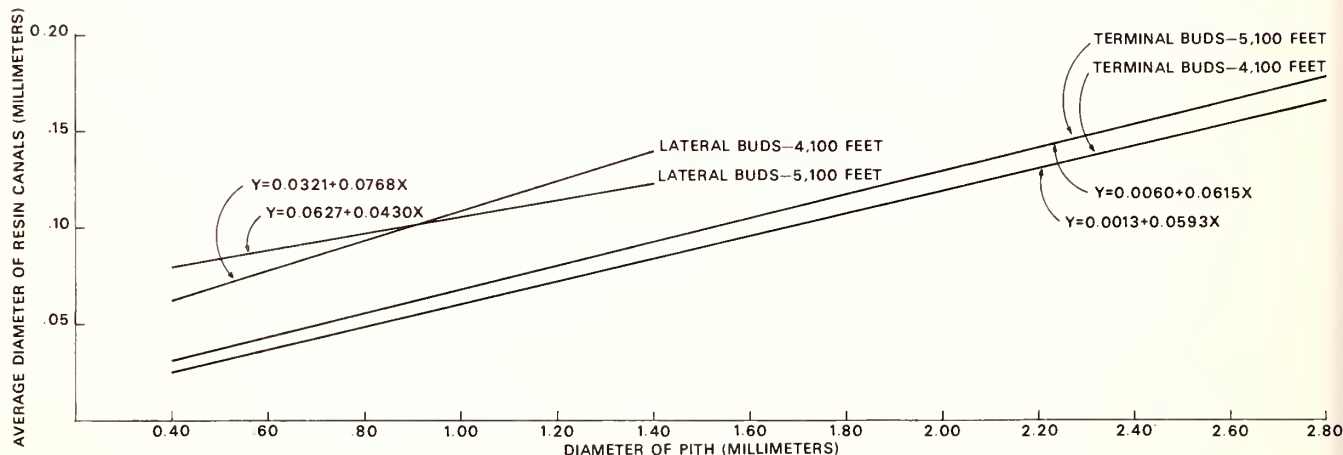


Figure 4.--Relationship between diameter of resin canals and diameter of pith in ponderosa pine buds, at one-third bud height, two elevations.

Weather conditions.--Records obtained during the study period indicated a more or less typical summer for this area, so that bud growth as recorded was probably normal. July and August were generally dry months, with mostly hot days and cool nights. A violent rainstorm on August 5, however, washed out several roads in the woods. Until late August, daily high temperatures exceeded 90° F. 2 or 3 days in each 7-day period, with the exception of one cool period from July 30 to August 5. Daily low temperatures ranged from 32° to 54°, but were mostly between 38° and 48°. Starting on August 13, a cooling trend was evident in the evening temperatures, and starting on August 26 a sharp downward trend in diurnal temperatures commenced. Freezing temperatures occurred on 2 of 6 nights during the final week of records, September 3-9, and snow fell on September 9 at the 5,100-foot plot.

Resin Canal Development and Time of Shoot Moth Attack

Sampling of Scotch pine in the Puget Sound area showed that larvae were attacking buds at an early stage of resin canal development. Primary resin canals had reached one-half bud height in only 60 percent of the terminal buds and 40 percent of the lateral buds. At this height all canals were less than 0.05-mm. diameter. At one-third bud height, resin canals in 10 terminal buds averaged 0.10-mm. diameter; canals in 13 terminal buds were less than 0.05-mm. diameter. All resin canals at one-third height in lateral buds were less than 0.05-mm. diameter.

Comparable resin canal development on ponderosa pine in the north-eastern Oregon plots in 1964 existed during the period July 2 to 8, as already described, some 23 to 29 days earlier than with Scotch pine in the Puget Sound area. Thus, at least part of the growth period presumably favorable to shoot moth attack would normally occur early in the season in east-side ponderosa pine stands, despite the late initiation of seasonal growth.

DISCUSSION

Results of the limited survey of bud complements on ponderosa pine suggest two different hypotheses. One is that young ponderosa pine stands can be classified on the basis of size of terminal buds and number of lateral buds per apical cluster, to indicate probable area differences in tree susceptibility to the shoot moth.

An alternative hypothesis is that size of terminal buds and number of lateral buds are directly related to an environmental factor, such as available moisture. Local variation in bud complements would then be considerable, and assessment of hazard would need to be based on recognizable local conditions rather than on relatively large areas.

The bearing of bud size and bud numbers on potential damage by the shoot moth is difficult to anticipate. Potential damage can be evaluated from the likelihood of success of initial attack or on the impact of subsequent feeding. Using the latter criterion, Miller (1967) concluded that less damage occurs with greater numbers of buds. However, in our potential problem with naturally growing pines, success of initial attack as influenced by bud size and number may be the proper criterion.

Bud size is probably an important factor in success of initial attack. In our studies, terminal buds showed a much greater capacity to produce resin than did lateral buds. The potential is in part influenced by bud size, which is directly related to resin canal area as indicated by Harris (1960). In addition, terminal buds have a greater number of resin canals than do lateral buds, as shown by our studies. Thus, larger terminal buds should be relatively resistant to shoot moth attack. Indeed, Brookes and Brown (1936) suggested that larvae attack lateral buds in autumn because terminal buds are excessively resinous.

Number of lateral buds has several ramifications. With regard to initial attack, it would appear that chances of successful attack by an individual larva would increase with a greater number of lateral buds. Further, more larvae could become established within a bud cluster. This line of reasoning appears substantiated by the large shoot moth populations found on ornamental pines with many lateral buds in the Puget Sound area.

The frequent absence of lateral buds from branch tips in natural stands of ponderosa pine in Oregon and Washington may constitute a strong resistance factor; larvae would be forced to compete for acceptable buds. Small numbers of larvae surviving to the spring-feeding period might still cause serious damage to these pines by migrating to the upper crown and attacking the leader. Actual numbers of larvae surviving up to this time and the probability of successful migration upward would be key aspects in estimating damage.

Timing of larval attack on lateral buds, in relation to development of resin canals, would also be an important factor in survival. Contrary to Wareing's assumption (in Harris 1960), development of lateral buds lags behind that of terminal buds, probably increasing their susceptibility to successful attack. However, development of lateral buds in the pine region is rapid in comparison with other areas, because growth is compressed into a short growing season. Whether phenology in the pine region will pose an obstacle to the shoot moth in adapting to ponderosa pine remains to be seen.

RESEARCH NEEDED

This study has provided some research leads for determining the hazard posed by the European pine shoot moth to natural stands, particularly of ponderosa pine. Quarantine sanctions are being obtained for studying the insect's behavior in relation to tree host characteristics in the pine region. Tests related to host characteristics should be conducted so as to determine:

1. Relative success of larval attack on lateral and terminal buds at different stages of resin canal development.
2. Relative success of larval attack on bud clusters with (a) no lateral buds, (b) one lateral bud, and (c) two or more lateral buds.
3. Value of large terminal buds and abundant lateral buds as an indicator of available moisture in pine stands.
4. Relation of stand density to bud production, resin production in buds, and success of larval attack.

CONCLUSIONS

1. Size of terminal buds and number of lateral buds on apical clusters together provide a means for defining conditions under which the shoot moth is tested on ponderosa pine.
2. Probable resin production of lateral buds is less than that of terminal buds. Lateral buds have fewer and smaller resin canals, and their development lags behind that of terminal buds.
3. Size of buds as indicated by pith diameter, and size of resin canals, are directly related in both lateral and terminal buds.
4. Differences in bud numbers, probable differences in resin production between terminal and lateral buds, and phenology may be related to susceptibility of ponderosa pine to the European pine shoot moth.

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